Chapter 3
Landscaping Techniques and Practices

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Landscaping Techniques and Practices

3.1 Landscape Plan and Design

Key factors in the design of bioretention facilities are careful selection of plant materials that can tolerate highly variable hydrologic changes and an overall planting plan that ecologically and aesthetically blends the facility into the landscape. Designing for ease of maintenance is also a critical element of any landscape plan and is covered in Chapter 5.

Bioretention facilities have a wide range of applications from suburban residential lots to ultra-urban streetscapes. It is the landscape designer's responsibility to analyze the surrounding site considerations and design a bioretention facility that maximizes water quality enhancement and landscape values. It is our intent to provide guidance for landscape planning and design to ensure successful bioretention facilities without discouraging individual creativity.

3.1.1 Site and Ecological Considerations

Consider interactions with adjacent plant communities including the potential to provide links to wildlife corridors. Adjacent plant communities should be evaluated for compatibility with any proposed bioretention area species. Nearby existing vegetated areas dominated by non-native invasive species pose a threat to adjacent bioretention areas. Invasive species typically develop into monocultures by out-competing other species. Mechanisms to avoid encroachment of undesirable species include providing a soil breach between the invasive community for those species that spread through rhizomes and providing annual removal of seedlings from wind borne seed dispersal. It is equally important to determine if there are existing disease or insect infestations associated with existing species on site or in the general area that may affect the bioretention plantings.

Blackhaw
Viburnum prunifolium .
White flowers are produced in spring, with the dark edible fruits maturing in autumn.

3.2 Plant Material Guidelines

3.2.1 Plant Selection Criteria

Plant species appropriate for use in bioretention areas are provided at the end of this section in Table 3.1: Plant Species Appropriate for use in Bioretention Areas. These species have been selected based on the ability to tolerate urban stresses such as:

- Expected pollutant loadings

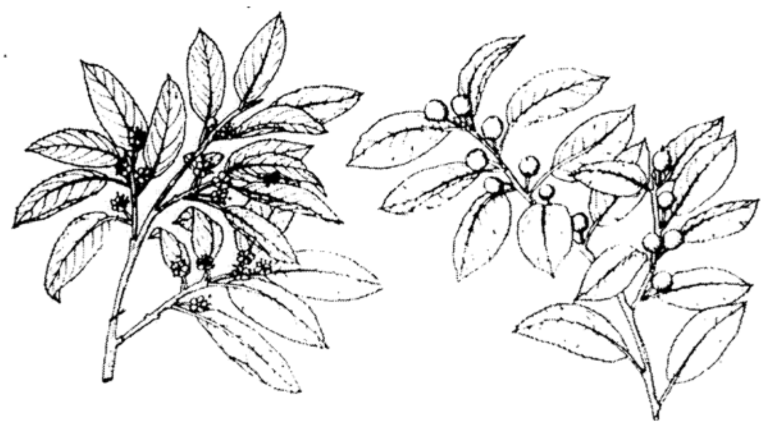
- Highly variable soil moisture conditions

- Ponding water fluctuations.

- Soil pH and texture

Important design considerations such as form, size, and type of root system are also included.

A key factor in designating a species as suitable is its ability to tolerate the soil moisture regime and ponding fluctuations associated with bioretention. Species are predominantly facultative (i.e., they are adapted to stresses associated with both wet and dry conditions); however, upland and wetland species have also been included. This is important because plants in bioretention areas will be exposed to varying levels of soil moisture and ponding depending upon the facility design and weather conditions. All of the species listed in Table 3.1 are commonly found growing in the Piedmont or Coastal Plain regions of Maryland as either native or ornamental species. Table 3.1 also provides information on light and soil requirements of individual plants.



Common Winterberry
Ilex verticillata (L.) A. Gray
Winter branches with the persistent bright red berries are sometimes gathered for use in Christmas decorations.

Designers considering species other than ones listed in Table 3.1 should consult the following reference material on plant habitat requirements, and consider site conditions to ensure that alternative plant material will survive:

- Brown, Melvin L., and Brown, Russell G., 1984 *Herbaceous Plants of Maryland*. Port City Press, Baltimore, MD.

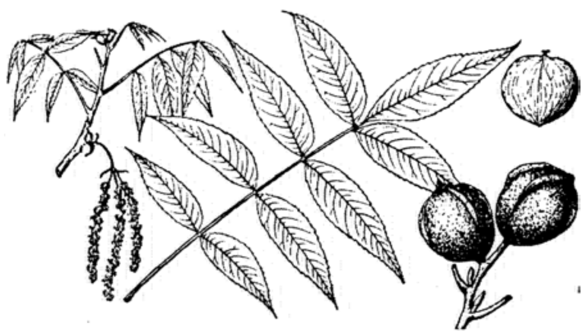
- Brown, Melvin L., and Brown, Russell G., 1984 *Woody Plants of Maryland*. Port City Press, Baltimore, MD

- Maryland-National Capital Park & Planning Commission, 1998. *Native Plants of Prince George's County, Maryland 1997-1998*

Jelich, Carol and Slattery, Britt, 1999. *Maryland Native Plants for Landscaping.* U.S. Fish and Wildlife Service, Chesapeake Bay Field Office.

Hightshoe, G.L., 1988. *Native Trees, Shrubs, and Vines for Urban and Rural America*. Van Nostrand Reinhold, New York, New York.

Reed, P.B. Jr., 1988. *National List of Species That Occur in Wetlands: Northeast*. United States Fish and Wildlife Service, St. Petersburg Florida.



Bitternut Hickory
Carya cordiformis (Wangenh.) K. Koch
Commonly occurring species that can grow in varied soil. conditions

Reasons for exclusion of certain plants from bioretention areas include inability to meet the criteria outlined above (pollutant and metals tolerance, soil moisture and ponding fluctuations, morphology, etc.) In addition, species that are considered invasive or not recommended by the Urban Design Section of the Maryland-National Capital Park and Planning Commission (Prince George's County, 1989), are not listed. Do not use species known to be invasive locally such as purple loosetrife (Lythrum salicaria), English ivy (Hedera helix), Japanese barberry (Berberis thunbergii) or burning bush (Euonymous alata.) For a national, up-to-date, multi-agency list of invasive plants consult the website, www.nps.gov/plants/alien/.

3.2.2 Plant Material Source

The plant material should conform to the current issue of the American Standard for Nursery Stock published by the American Association of Nurserymen. Plant material should be selected from certified nurseries that have been inspected by state or federal agencies. The botanical (scientific) name of the plant species should be in accordance with a standard nomenclature source such as Gray's Manual of Botany [1] or Hortus III[2]

Some of the plant species listed in Table 3.1 may be unavailable from standard nursery sources. These are typically species native to Maryland and may not be commonly used in standard landscaping practices. Designers may need to contact nurseries specializing in native plant propagation. Lists of some native plant nurseries are provided in Appendix D. All plant material specified must be propagated, germinated or otherwise developed from nurseries located east of Tennessee in Hardiness Zones 6 or 7. Verify that plants have not been wild collected (unless they have been obtained from a documented plant rescue site).

3.2.3 Plant Material Layout

The layout of plant material can be a flexible process; however, the designer should follow some basic guidelines. As discussed above, the designer should first review Table 3.1. The checklist table can help expose any constraints that may limit the use of a particular species and/or where a species can be installed.

There are two guidelines that should apply to all bioretention areas. First, woody plant material should not be placed directly within the entrance-inflow path. Besides possibly concentrating flows, trees and shrubs can be damaged as a result of the flow causing soil to be washed away from the root ball. Second, keep in mind that all areas of the facility will not be subjected to the same depth of ponding and saturation. The gentle bowl shaped configuration of the facility lends itself to differing zones of saturation. This provides an opportunity to utilize plants that cannot tolerate saturated conditions along the outside perimeter of the facility. This can be especially useful when visually linking a facility into an adjacent area landscaped with a formal theme.

Button Bush
Cephalanthus occidentalis L.
Forms dense thickets that serves as excellent cover and nesting sites for birds.

Often designers will find that the environmental factors such as sun, shade, wind and temperature vary not only on site, but also between bioretention areas. As a result, the designer may need to consider the placement of each plant. An example would be to consider placing evergreen trees or other wind tolerant species on the northern end of a bioretention area, against cold winter winds.

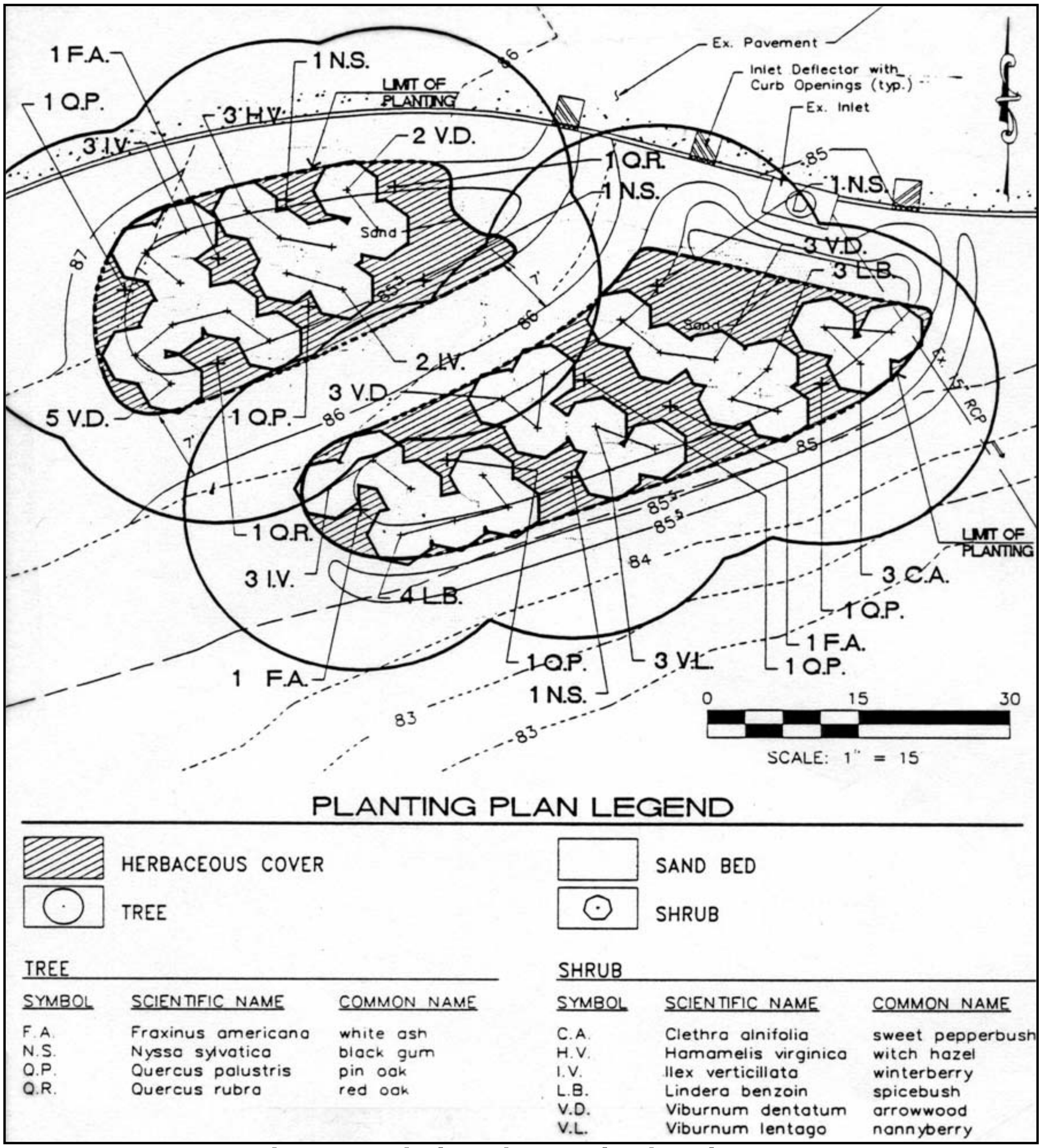


Fig. 3.1 Typical Landscape Planting Plan

3.2.4 Installation

The success of bioretention areas is very dependent on the proper installation specifications that are developed by the designer and subsequently properly followed by the contractor. The specifications include the procedures for installing the plants and the necessary steps taken before and after installation. Specifications designed for bioretention should include the following considerations:

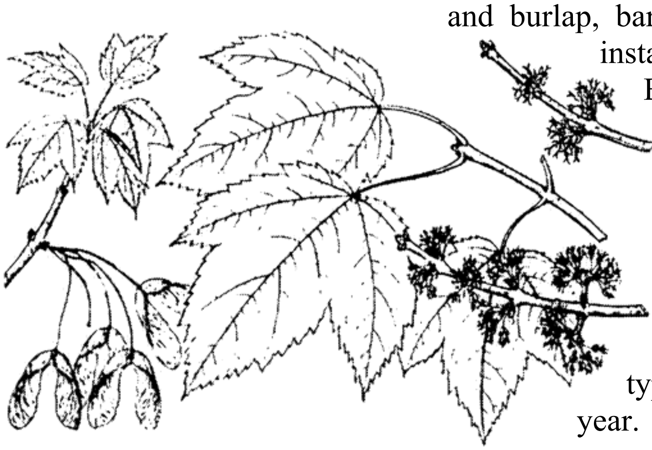
- Sequence of Construction
- Contractor's Responsibilities

- Planting Schedule and Specifications
- Maintenance
- Warranty

The sequence of construction describes site preparation activities such as grading, soil amendments, allowance for compaction of soils, and any pre-planting structure installation. It also should address erosion and sediment control procedures. Erosion and sediment control practices should remain in-place until the entire bioretention area is completed. Ideally, bioretention areas should be constructed concurrently with final grading and permanent site stabilization operations.

The contractor's responsibilities with respect to landscaping and plantings shall be itemized within the contract specifications. See Appendix A for landscaping guidelines. The responsibilities include any penalties for unnecessarily delayed work, requests for changes to the design or contract, and exclusions from the contract specifications such as vandalism to the site, etc.

The planting schedule and specifications include type of material to be installed (e.g., ball and burlap, bare root, or containerized material), timing of installation, and post installation procedures. Balled and burlapped and containerized trees and shrubs should be planted during the following periods: March 15 through June 30 and September 15 through November 15. Ground cover excluding grasses and legumes can follow tree and shrub planting dates. Grasses are best seeded in late summer through early fall. Legumes typically should be planted in the spring of the year. The planting of trees and shrubs should be performed by following the planting specifications set forth in the Prince George's County Landscape Manual (October 1989), except that trees should not be staked unless the site is exceptionally windy. The County specifications provide guidelines that insure the proper placement and installation of plant material. Designers may choose to use other specifications or to modify the County specifications. However, any deviations from the County specifications need to address the following:



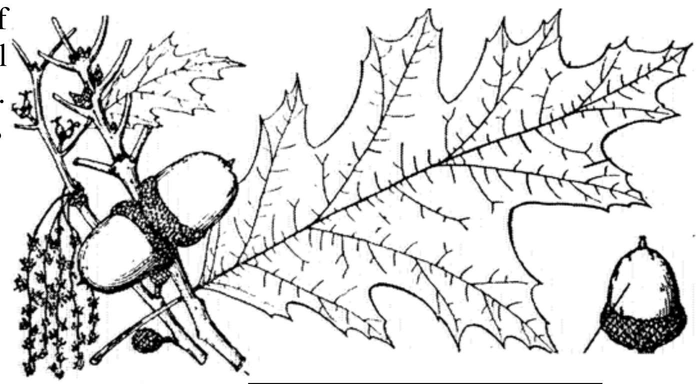
Red Maple
Acer rubrum
Grows equally well along the borders of swamps and dry upland sites.

- transport of plant material
- preparation of the planting pit
- fertilization (if applicable)

- installation of plant material
- stabilization seeding (if applicable)
- watering and general care

Maintenance needs of bioretention areas differ little from other landscape areas. However, it is important to use maintenance practices in and around bioretention areas, which will not compromise the facility's pollutant-removal capacity. Avoid blocking inflow entrance points with mounded mulch or raised plantings blocking flow dispersion over the entire surface area of the facility.

Adopting a low input maintenance regime will lessen the chance of overwhelming the facility with pollutant loadings above design capacity and will protect soil life. Reducing pesticide use will also reduce the risk of damage to bioretention plants, beneficial birds and insects, and soil organisms. Moreover, such conservation techniques can also save money. For example, switching to integrated pest management (IPM) has allowed the National Arboretum in Washington DC to cut pesticide costs an estimated 80%[3]. For more information about IPM and other low-input techniques see the Alliance for the Chesapeake Bay's BayScapes publications. Maryland Cooperative Extension also has a number of publications, including Mimeo #HG 62*, IPM: A Common Sense Approach to Managing Problems in your Landscape* and Bulletin *350, Landscape IPM Guidelines for Integrated Pest Management of Insect & Mite Pests on Landscape Trees.*



Northern Red Oak
Quercus rubra .
Hybridizes with black oak, willow oak, shingle oak, and bear oak.

3.2.5 Warranties

Typically, a warranty is established as a part of any plant installation project. The warranty covers all components of the installation that the contractor is responsible for. A professional landscape contractor should perform the plant and mulch installation for bioretention. An example of standard guidelines for landscape contract work is provided below:

- The contractor should maintain a care and replacement warranty for all plantings in accordance with industry standard and/or contractual arrangements with the owner.

- As a minimum, the period of care and replacement shall begin after inspection and approval of the complete installation of all plants and continue for one year.

- Plant replacements shall be in accordance with the maintenance schedule.

3.3 Soil Guidelines

3.3.1 Soil Medium Guidelines

The soil medium play an important role in the improvement of water quality through the use of bioretention systems. The soil is a three-phase system composed of gas, liquid, and solid, each of which in the proper balance is essential to the pollutant removal achieved through bioretention. The soil anchors the plants and provides nutrients and moisture for plant growth. The unsaturated pore space provides plant roots with the oxygen necessary for metabolism and growth. Microorganisms inhabit the soil environment. They form an essential link providing nutrients in the appropriate forms for plant uptake. Microbes, microfauna, macrofauna, and living roots are present in immense numbers in healthy soil. In fact, the living organisms within the top 6 inches of an acre of soil can weigh as much as 20,000 pounds[4].

Green Ash
Fraxinus pennsylvanica
Seed crop is an important food for cardinals, finches, and squirrels.

3.3.2 Soil Texture and Structure for Soil Medium

A desirable planting medium:

- is highly permeable to allow infiltration of runoff,
- provides adsorption of organic nitrogen and phosphorus.
- has high porosity and hydraulic conductivity

This can be achieved with a prepared soil mix consisting of 50-60% sand, 20-30% leaf compost, and 20-30% topsoil. Where a prepared soil mix is not used, it is recommended that the planting soils for bioretention be composed of a chiefly sandy soil. A strong granular or crumb-like structure is also desirable. Suitable planting soils for bioretention areas are indicated on the USDA soil triangle in Figure 2.4. These soils have a clay content less then 5%. Water balance computations in Appendix C indicate that soils with infiltration rates greater than 0.5 inches/hr are suitable for bioretention. Sandy loam, loamy sand, and loam soils have minimum infiltration rates ranging from 1.0 to 2.41 in/hr. (Other types of loamy soils such as silt loams, and sandy clay loams have infiltration rates of 0.27 inches/hr or lower and are *not* suitable for bioretention.) When insitu soils are saturated or have a high clay/silt content, underdrains must be used to help regulate planting soil infiltration rates and provide a margin of safety. For marginal soils, (.27-1.0 inches/hr), a site specific recommendation from geotechnical report must be consulted.

3.3.3 Available Soil Moisture

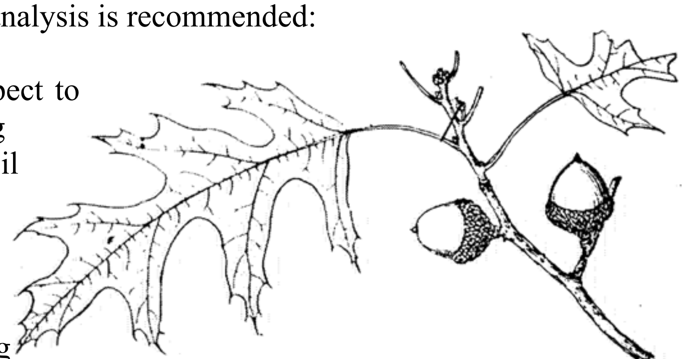
Bioretention areas are typically designed with soils that are course grained sand to allow for high filtration capacity. This presents a problem for retaining available soil moisture, and hence, available water for plant growth. When sandy textured soils are used in conjunction with underdrains, the available soil water is reduced significantly, and may cause the soil to reach the wilting coefficient. If this point is reached, supplemental watering is necessary to sustain the plant growth. Overwatering should be avoided, however, since excessive irrigation could lead to nutrient leaching from the facility. The mulch layer can help keep the soil moisture capacity higher and reduce the need for watering.

3.3.4 Soil Investigation and Testing Criteria for Bioretention Suitability

Whenever bioretention is to be utilized for a development, close attention to the soil conditions and limitations are of obvious importance. To help the designer determine the extent of testing required at the earliest stage possible, and to reduce the cost associated with those tests, the following sequence of analysis is recommended:

1. Determine the site limitations with respect to environmental constraints, paying particular attention to the hydrologic soil groups encountered on the site.

2. Using the soils information, delineate the HSG's A, B, C & D. Lay out the lots and roadways to avoid placing impervious surfaces on hydrologic soil groups A & B, which typically have high infiltration rates.



Scarlet Oak
Quercus coccinea Muench.
Leaves turn a bright red or scarlet in autumn.

3. Consider topography- Lay out the lots and roadways to minimize cut and fill, as well as impacts to A & B soils. Overlay the topographic layer with the development layout and the soils map delineation.

4. For areas where development of new impervious areas are over hydrologic soil groups C & D, bioretention is not recommended unless an underdrain system discharge is provided. Generally, C & D soils are not well drained.

5. For areas where development of new impervious areas are over A & B soils, bioretention will typically work well without the benefit of underdrain systems. However, soil testing is required to ensure adequate infiltration rates and underdrains are strongly encouraged.

6. For bioretention areas that do not incorporate underdrain systems, one soil test per facility is required that includes the following as a minimum:

   - Identification of soil horizons and the corresponding USDA soil classification
   - Grain size distribution (sieve analysis) indicating the % clay, sand and silt.
   - Depth to the groundwater table or impervious layer (>2 feet below the bioretention invert), if present.
   - Depth of test shall be at least 3 feet below the proposed invert.
   - Infiltration rates must be determined using standard acceptable practices such as a percolation test.

7. Check for utility lines before digging.

3.3.5 Soil Acidity

In a bioretention scheme, the desired soil pH would lie between 5.5 and 6.5[5]. Soil acidity affects the ability of the soil to adsorb and desorb nutrients, and also affects the microbiological activity in the soil. In the Optimization of Bioretention experiment (Davis et al, 2000), it was found that the metals adsorbtion rate increases significantly at the upper and lower ranges of the pH scale. Test site soils to determine pH as part of the geotechnical report. In lieu of specifying pH however, the prepared soil mix has been shown to provide adequate pollutant removal rates.

3.4 Plant Growth and Soil Fertility

Shining Sumac
Rhus copallina L.
Attracts birds and other wildlife

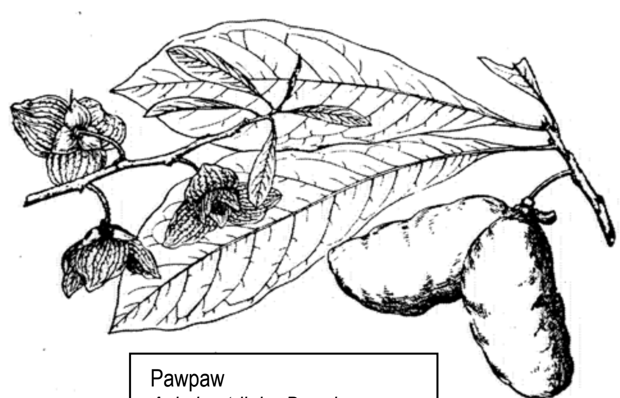
A discussion of plant growth and soil fertility development over time is important for estimating the success and lifespan of bioretention areas. The physical, chemical, and biological factors influencing plant growth and development will vary over time as well as for each bioretention area. However, there are certain plant and soil processes that will be the same for all bioretention areas.

3.4.1 Plant Growth

The role of plants in bioretention includes uptake of nutrients and pollutants and evapotranspiration of stormwater runoff. The plant materials, especially ground covers, are expected to contribute to the evapotranspiration process within the first year of planting. However, trees and shrubs that have been recently planted demonstrate slower rates of growth for the second year due to the initial shock of transplanting. The relative rate of growth is expected to increase to normal rates after the second growth season.

The growth rate for plants in bioretention areas will follow a similar pattern to that of other tree and shrub plantings (reforestation projects, landscaping). For the first two years, the majority of tree and shrub growth occurs with the expansion of the plant root system. By the third or fourth year the growth of the stem and branch system dominates increasing the height and width of the plant. The comparative rate of growth between the root and stem and branch system remains relatively the same throughout the lifespan of the plant. The reproductive system (flowers, fruit) of the plants is initiated last.

The growth rates and time for groundcovers to become acclimated to bioretention conditions is much faster than for trees and shrubs. The rate of growth of a typical ground cover can often exceed 100 percent in the first year. Ground covers are considered essentially mature after the first year of growth. The longevity of ground covers will be influenced by the soil fertility and chemistry as well as physical factors, such as shading and overcrowding from trees and shrubs and other ecological and physical factors.



Pawpaw
Asimina triloba Dunal
Early settlers made yellow dye from the ripe pulp of the fruits

Plants are expected to increase their contribution to the bioretention concept over time, assuming that growing conditions are suitable. The rate of plant growth is directly proportional to the environment in which the plant is established. Plants grown in optimal environments experience greater rates of growth. The primary factors determining this are soil fertility, water availability, and good drainage.

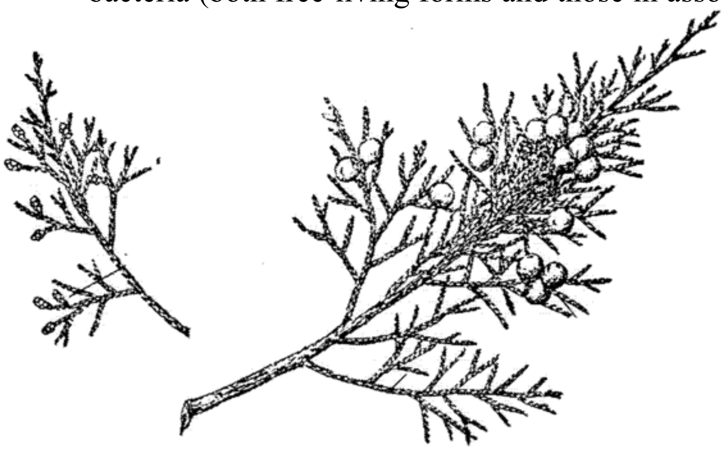
3.4.2 Soil Fertility

In traditional, intensively cropped landscapes, soil fertility (and especially the level of available nitrogen) is considered the limiting factor to plant growth. As already noted, however, human actions have considerably altered the cycling of nitrogen. By design, Bioretention facilities are located in areas where nutrients (especially nitrogen) are significantly elevated above natural levels. In addition, many of the native plants recommended in Table 3.1 do not need large nutrient inputs to flourish. Therefore, it is unlikely that soil fertility will be the limiting factor in plant growth, and thus fertilization would be unnecessary. Excess fertilization, (besides compromising the facility's pollutant reduction effectiveness) leads to weak plant growth, promotes disease and pest outbreaks, and inhibits soil life.

If soil fertility is in doubt, a simple soil test can resolve the question. If fertilization should become necessary, an organic fertilizer will provide nutrients as needed without disrupting soil life. Organic fertilizers release nutrients slowly and contribute organic matter to improve soil conditions. Test soil mixture as part of geotechnical report.

3.4.3 Microbial/Biochemical Action

The microbial/biochemical actions that take place in a bioretention facility are presumed to be important for enhancing the pollutant removal processes. Microbes are the unseen machines for recycling nutrients and decomposing organic materials. Nitrogen-fixing bacteria (both free-living forms and those in association with plants) convert atmospheric nitrogen into forms which plants can utilize. Decomposers break down organic matter, releasing plant nutrients and forming humus. Fungi then facilitate nutrient absorption into plant roots. Humus (partially decomposed organic matter) stores nutrients. In fact, a soil's ability to store nitrogen increases as the organic layer is built up until equilibrium is reached. Besides storing nutrients, humus helps the soil retain both oxygen and water. In turn, fungi link particles of organic matter in the litter layer and upper levels of the soil, forming a web that resists erosion and retains moisture. For all these reasons, careful attention must be paid to the selection of the planting soils for bioretention.



Eastern Redcedar
Juniperus viginiana
The most drought resistant conifer in the East.

3.4.4 Soil Horizon Development

Initially, soil in bioretention areas will lack a mature soil profile. It is expected that over time discrete soil zones referred to as horizons will develop. The development of a soil profile and the individual horizons is determined by the influence of the surrounding environment including physical, chemical, and biological processes. Two primary processes important to soil horizon development are microbial action (decomposition of organic material) and the percolation of runoff in the soil.

Soil microbes, microfauna, and macrofauna; together with living plant roots, build soil from minerals and organic matter. Just as geologic processes and succession create a particular ecosystem (e.g. rainforest, prairie, or salt marsh) above ground, these processes create characteristic soil profiles and complex ecosystems below ground.

Horizons expected to develop in bioretention areas include an organic layer, followed by two horizons where active leaching (eluviation) and accumulation (illuviation) of minerals and other substances occur. The time frame for the development of soil horizons will vary greatly. As an average, soil horizons may develop within three to ten years. The exception to this is the formation of the organic layer often within the first or second year[6]. The evaluation of soil fertility in bioretention may be more dependent on the soil interactions relative to plant growth than horizon development. The soil specified for bioretention is important in filtering pollutants and nutrients as well as supplying plants with water, nutrients, and support. Unlike plants that will become increasingly beneficial over time, the soil will begin to filter the storm water runoff immediately. It is possible that the ability to filter pollutants and nutrients may decrease over time, reducing the soil fertility accordingly. Substances from runoff such as salt and heavy metals eventually disrupt normal soil functions by lowering the cation exchange capacity (CEC). The CEC, the ability to allow for binding of particles by ion attraction, decreases to the point that the transfer of nutrients for plant uptake can not occur. However, the environmental factors influencing each bioretention area will vary enough that it is difficult to predict for the lifespan of soils. Findings from other stormwater management systems suggest an accumulation of substances eliminating soil fertility within five years. Should this occur, organic matter may be added by the addition/replacement of the mulch material. The monitoring of soil development in bioretention areas will help develop better predictions on soil fertility and development.

Green Ash
Fraxinus pennsylvanica Marsh.
Green ash is widely planted for shade and streetscapes.

Some facilities in the ground over 8 years, appear to have soil structures developing that actually enhance the filtering capability.

3.5 Mulch Layer Guidelines

The mulch layer plays a vitally important role in the overall bioretention design. This layer serves to prevent erosion and to protect the soil from excessive drying. Soil biota existing within the organic and soil layer are important in the filtering of nutrients and pollutants and assisting in maintaining soil fertility. Bioretention areas can be designed either with or without a mulch layer. If a dense herbaceous layer or groundcover (70 to 80% coverage) is established, a mulch layer is no longer necessary. Areas should be mulched once trees and shrubs have been planted. Any ground cover specified as plugs may be installed once mulch has been applied.

The mulch layer recommended for bioretention may consist of either a standard landscape fine shredded hardwood mulch or hardwood chips. Both types of mulch are commercially available and provide excellent protection from erosion for very low velocity flows, although shredded is less likely to float.

The mulch may be either aged or fresh to maximize nitrogen and metal uptake by the facility. Mulch should be free of weed seeds, soil, roots, or any other substance not consisting of either bole or branch wood and bark. The mulch should be uniformly applied approximately 2 to 3 inches in depth. Mulch applied any deeper than three inches reduces proper oxygen and carbon dioxide cycling between the soil and the atmosphere, and keeps plant roots from making good contact with the soil.

Grass clippings are *unsuitable* for mulch, primarily due to the excessive quantities of nitrogen built up in the material. Adding large sources of nitrogen could limit the capability of bioretention areas to filter the nitrogen associated with runoff and possibly create a net gain of nitrogen.

While mulching provides an important function in the bioretention process, a herbaceous layer or groundcover is preferred over mulching for several reasons[1]. First, the mulch material has the ability to float up-and-out during heavy rain events. Second, the herbaceous layer provides more opportunities to capture and hold water though interception and evapotranspiration. Finally, providing thick, lush, groundcover increases the aesthetic appeal and adds to the landscape character. A combination of groundcover and mulch is an equally preferable option.

3.6 Bioretention Types & Applications

3.6.1 Forest-Type and Forest Fringe Bioretention Facilities

Frosted Hawthorn
Crataegus pruinosa (Wendl.) K. Koch
Small tree located from Newfoundland to North Carolina.

The original bioretention concept was modeled from the hydrologic characteristics and properties of a terrestrial forest ecosystem. The forest community model for stormwater management was selected based upon a forest's documented ability to cycle and assimilate nutrients, pollutants, and metals through the interactions among plants, soil, and the organic layer. This theme is appropriate where the facility is located at wooded edges, in the rear of residential lots, or where a wooded buffer is desired. Where space is at a premium, large shrubs may be used for the canopy layer with smaller shrubs and an assortment of perennials underneath. A sample planting plan is shown in Fig. 3.1

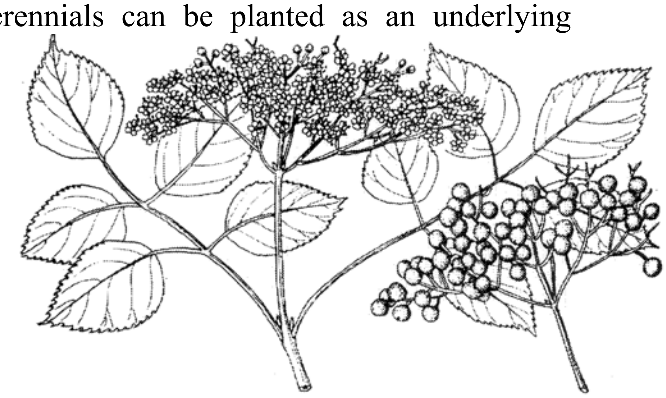
[1] In areas expected to have high metal loadings (industrial and institutional land uses) mulching is preferred over a herbaceous groundcover.

Site trees on the perimeter of bioretention areas, to maximize the shading and sheltering of bioretention areas to create a microclimate which will limit the extreme exposure from summer solar radiation and winter freezes and winds.

The final plant material layout should resemble a random and natural placement of plants rather than a standard landscaped approach with trees and shrubs in rows or other orderly fashion.

A minimum of three species of trees and three species of shrubs should be selected to ensure diversity. This will protect the system against collapse from insect and disease infestations and may ensure a more constant rate of evapotranspiration and nutrient and pollutant uptake throughout the growing season.

Perennials can be planted along the edge of the facility where color and seasonal interest are desired, and shade tolerant perennials can be planted as an underlying herbaceous layer throughout the rest of the facility.



American Elder
Sambucus canadensis L.
Prefers rich moist soils along streams and rivers, margins of woodlands, fence rows, and railroad right-of-ways.

Utilize native plants in the design. Native species demonstrate a greater ability of adapting and tolerating physical, climatic, and biological stresses (Metropolitan Washington Council of Governments, 1992).

Select herbaceous ground covers to prevent erosion of the mulch and the soil layers. Select at least 3-4 species of herbaceous groundcover. Suitable herbaceous ground covers are identified in Table 3.1.

Two to three shrubs should be specified for each tree (2:1 to 3:1 ratio of shrubs to trees).

Where the plant material for the facility is utilized to meet the residential landscape requirements or street tree requirement trees may be 2.5 inches in caliper. All other trees shall be specified as >1.0 inch caliper.

Shrubs shall be 3 to 4 feet in height or 18 to 24 inches in spread.at installation Mixed trees and shrubs can be planted as close as 7 feet; and shrubs alone from 4 to 7 feet apart.

Ground cover may be as seed or, preferably, plugs.

Table 3.2. Recommended Tree and Shrub Spacing (Forested Bioretention)			
	Tree Spacing (feet)	Shrub Spacing (feet)	Total Density (stems/acre)
Maximum	19	12	400
Average	12	8	1,000
Minimum	11	7-4	1,250

Table 3.2: Forested bioretention tree and shrub spacing guidelines

3.6.2 Ornamental Garden

When bioretention facilities are utilized for water quality improvement in residential areas, the aesthetics and visual characteristics of the design must be a prime consideration. A facility located at the entrance to a commercial building, a residential neighborhood or located in the front yard of a residential lot may provide a landscaped focal point for the community. It is appropriate in these settings to choose plants that have ornamental characteristics that visually link the facility into the surrounding landscape. In all cases, the landscaping requirements for bioretention are flexible enough to provide the designer with opportunities to meet the residential landscape requirements required by Maryland National Capital Park and Planning Commission.

- Consider the bioretention facility a mass bed planting. The entire facility shall be planted at a density that the foliage will completely cover the facility after the second growing season.

- Consider using the dominant species of plant material used around the entrance to the home to visually link the bioretention facility with the home.

- Choose a variety of plant species that will add interest to the bioretention facility with each changing season. Perennials provide vibrant colors from early spring through fall while ornamental grasses and evergreen or berry producing shrubs can add winter interest.

- Species that require regular maintenance (shed excessive amounts of fruit or are prone to storm damage) should be restricted to areas of limited visibility and away from pedestrian and vehicular traffic.

- Where the facility is located below overhead utilities, select tree species that comply with local utility height and clearance requirements.

Where the ornamental garden receives runoff from the street, choose salt tolerant species. In the Mid-Atlantic Region, most salt applications will wash through the soil and not adversely affect the plants. However, it is still recommended that snow and ice be treated with sanding applications rather than salting. If salt is used, apply sparingly within bioretention drainage areas. Never use fertilizer to melt ice. For more information see Maryland Cooperative Extension Fact Sheet 707, *Melting Ice Safely.*

Mulch the entire bed with 2 to 3 inches of hardwood mulch. Fresh bark mulch should be used when possible to maximize nitrogen retention. If possible, use shredded instead of the "chip" variety to minimize floating action. All mulch should be free of foreign material including plant material.

3.6.3 Open Space Meadows

Open space meadows are a very practical application of the bioretention BMP. By proper design, the long-term maintenance costs associated with common or open space areas can be reduced significantly with the use of bioretention meadows. Typically, open spaces are maintained as nondescript grassed areas with minimal landscape features. A bioretention meadow, composed of ornamental grasses interlaced with wildflowers, does much more. Bioretention meadows: improve water quality, provide aesthetic value, benefit wildlife, and reduce costs.

Like a forest, a meadow is a structured community of plants occupying different levels above and below ground. Meadows, like forests, also undergo ecological succession, with short-lived pioneer species being gradually replaced by a "climax" community. A variety of grasses and wildflowers are generally interspersed throughout the site. Drifts of a particular species, however, may develop over time in response to variations in moisture or as a consequence of ecological succession. While it is not difficult to design and establish a meadow, it is important to use plant communities and techniques specifically adapted to local conditions. For guidance on developing meadow gardens consult the US Fish and Wildlife Service, Chesapeake Bay Field Office, BayScapes Program.

Black Tupelo
Nyssa sylvatica Marsh.
The small greenish flowers are an excellent source of nectar for bees.

3.6.4 Meadow Garden

A meadow garden is a more designed, less natural approach to using meadow plants. Plants may be seeded in sweeping bands of color within the meadow or zones of short, medium, and tall plant mixes can be seeded to provide height progression. In small enough areas, plants may be individually placed and arranged.

3.6.5 Commercial Sites

When bioretention facilities are located at the entrance to a commercial building and provide a landscaped focal point for the site, an ornamental garden theme is appropriate. Refer to the guidelines under ornamental garden for information on the design of these facilities. Other facility design themes such as forest or meadow can add beauty and wildlife habitat to commercial open space areas. Where the facility is located in a parking island or median, additional design criteria also apply.

- Consider the size of the facility and determine if adequate planting soil exists to support large shade trees. It may be more appropriate to choose smaller ornamental species.
- The facility may be sited where it is exposed to wind, sun, salt and toxics from parking lots that will affect the candidate species.

- Bioretention facilities located along roads or in the median of parking lots must be analyzed to determine if there are any traffic considerations or safety issues. An adequate site distance must be maintained along roads and intersections to provide for the safe flow of traffic. Choose low growing plants and shrubs that do not block the view of oncoming vehicular or pedestrian traffic. The Department of Public Works and Transportation, Engineering Office, has additional information on maximum heights of plants allowed in the medians of County Roads and information on tolerance to pollution, salt, and wind.

3.7 Bioretention Plant List

The following planting list has been derived from multiple sources and includes a variety of species that conform to many parameters and conditions. The original bioretention list from the first manual on bioretention has been more than doubled to include 150 hardy plant species (mostly natives) that can sustain themselves through climatic and seasonal fluctuations. The original listing included over 40 parameters such as tolerance to salt, moist roots, sun and shade, etc. Some of those parameters are listed in the plant list comments column, but the designer should also consult other landscaping sources for proper application. The listing is only suggested species based on our experience and others' relating to bioretention applications. Additions and modifications to the listing are welcome and encouraged.

NOTES: The following list contains plants adapted to a variety of water regimes. This will allow designers to select plants appropriate to any combination of bioretention design and site constraints. **Please be advised, however, that not all plants will do well in all situations, so it is important to match the plants to the expected conditions**. All the plants listed are perennials, since perennial plantings require less maintenance than the traditional bedding out of annuals. Annuals, however, can be usefully employed as cover crops or nurse crops for meadow plantings and to provide temporary color in newly established plantings.

Soil Moisture & Drought Tolerance –

Saturated soils are wet for a significant portion of the growing season except during times of drought.

Moist soils are damp for most of the growing season, except during times of drought. They may occasionally be saturated. Some notes are included on flood tolerances and which plants can function as emergents, but designers should consult wetland references for specifics on water depths and durations tolerated.

Drought-tolerant perennials will do well in areas where water does not remain after a rain, and will not need supplemental watering in all but the most extreme droughts.

Light Requirements - *Full sun* means direct sunlight for at least six hours a day during the plant's growing season. *Partial shade* means three-six hours of direct sunlight or a site with lightly filtered sun during the plant's growing season. *Shade* means less than three hours of direct sunlight or a site with heavily dappled sun during the plant's growing season.

Geographic Restrictions – While this list was designed for Prince George's County, the plants included should do well within the middle section of the Mid-Atlantic region. Care should be taken, however, in utilizing the list elsewhere. Plants listed here may not be cold hardy in the extreme north or heat hardy in the extreme south. Similarly, a plant that is drought tolerant in this generally humid area may not be adapted to drier conditions in Western regions. Finally, users from other regions should be cautious and check local invasive plant lists since native plants from one region may become invasive in another setting.

The list was prepared by Carole Ann Barth, Environmental Planner, PPD, DER. Ms. Barth thanks the following experts for reviewing the list: Carole Bergmann, MNCPPC, Stacy Miller, MNCPPC, Britt Slattery, USFWS, Craig Tufts, NWF, Jean White, NWF. Thanks are also due to Bill Robbins, for technical assistance. The planting list is available separately from the Bioretention Manual.

[1] Fernald, 1950
[2] Bailey and Bailey, 1975
[3] Natural Resources Defense Council, Stormwater Strategies, May 1999
[4] Gershuny, Grace, Start With The Soil, 1993
[5] Tisdale and Nelson, 1975
[6] Brady, 1984